

SENSITIVITY OF SOLID EXPLOSIVES--MINIMUM ENERGY OF A
DANGEROUS IMPACT

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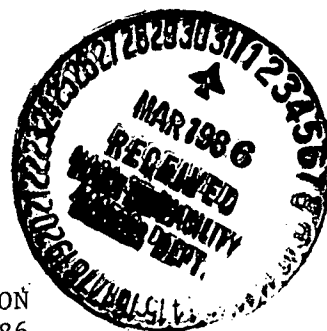
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16. Abstract A method which uses initiating explosives for determining the sensitivity of solid explosives is described. The energy index of sensitivity is determined by the mechanical properties of the explosives. The results of the calculations are discussed.			
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SENSITIVITY OF SOLID EXPLOSIVES--MINIMUM ENERGY
OF A DANGEROUS IMPACT

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The phenomenon of the sensitivity of explosives to external influences is based on the processes of excitation and development of propagating explosive conversion, whose mechanism and more detailed sequence depend on the form and the conditions of the influence. As applied to an impact, this sequence consists of local heating and combustion [1-6]--the first stage; the development of the conversion from the focus in the compression zone [3-7] is the second stage, and its transfer to the surrounding explosives [3,6,8,9]--is the third stage. An impact in which all three stages are carried out is called a dangerous impact. In the theory of sensitivity, the problem of determining it can be formulated on the basis of the "minimal action" principle [6], according to which the sensitivity of the explosive characteristics must be determined by the most dangerous influence. There are several of these problems: The determination of the dangerous influences and the least dangerous influence; the verification of the criterion of determination and the corresponding test methods (or the methods of measuring the parameters which determine the sensitivity).

In the majority of devices which are used for testing explosives for sensitivity, the entire charge is subjected to loading, and the last stage is excluded in general. This makes them unsuitable for studying a dangerous impact and determining the sensitivity. They can only be used to study the process and parameters of initiation. In this sense, the most widely used equipment is that with free flow of substances [1-6,10,11], where the deformation conditions are the simplest (Figure 1a);

*Numbers in margin indicate pagination of foreign text.

F--impact direction). It has been shown [6] that after deformation, which is close to elastic deformation, the charge is destroyed at a pressure of

$$P_{np} = \sigma_{np} \left(1 + \frac{D}{3\sqrt{3} h_0} \right), \quad (1)$$

where σ_{np} is the explosive ultimate strength; h_0 and D —width and diameter of the charge. If the quantity P_{np} exceeds a certain critical value

$$P_{np} \geq P_{kp}, \quad (2)$$

then combustion occurs in the destruction process due to heating of the explosive on the slip planes. The existence of a critical pressure follows from the necessity of increasing the melting point (which limits the temperature in the case of friction [3]) up to the level of the critical temperature of focal thermal explosions [5,6]. The study [12] presents another opinion on the role of pressure. It is related to the necessity of producing a heated layer corresponding to stationary heating, in the case of focus explosions. Relations (1) and (2), when the signs are equal, determine the initial conditions which are critical for excitation of the explosion. The initiation thus occurs under conditions of a pressure drop at a thickness of h_{nn} , which is less than the initial value [10]. /36

All three stages are considered in the method which uses initiating explosives for determining the sensitivity [8] (Figure 1,d). Using this method, the impact loading is transferred to the section of the charge which is bounded by the striker area ($D = 1.5$ mm). Using detonation as the working mode of the explosive conversion, we can write the condition for its transfer

$$h_{nn} \geq \Delta_{kp}, \quad (3)$$

where Δ_{kp} is the critical width of the layer which can be detonated and which is located on a rigid base. Based on the critical conditions of excitation of the charge (1)–(2), the necessary condition for the detonation transfer (3) and assuming for purposes of simplicity that the second stage is performed, $h_{nn} \approx h_0$, the study [6] made a quantitative determination of the sensitivity using the minimum force in the case of impact

$$F_{min} = \frac{\pi}{4} D_{min}^2 P_{kp} \quad (4)$$

and the minimum diameter of the loading area

$$D_{min} \approx 3 \sqrt[3]{\frac{P_{kp} - \sigma_{np}}{\sigma_{np}} \Delta_{kp min}} \quad (5)$$

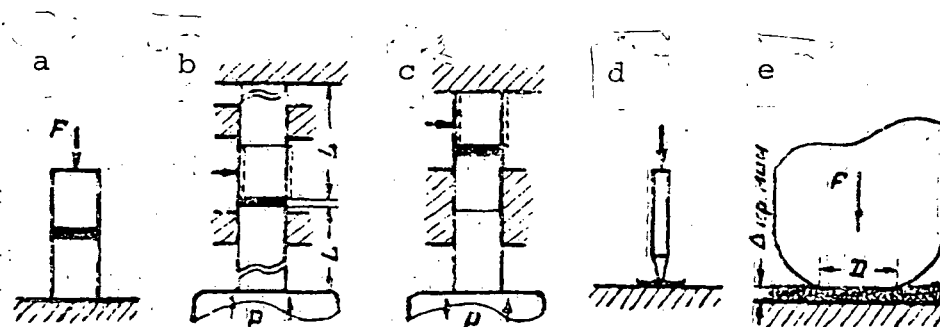


Figure 1. Diagram for determination of the sensitivity of initiating explosives

Minimization of the influence is done using the form of the loading area and the explosive density as a non-fixed parameter of state. For very powerful explosives, the greatest detonation capacity, which is characterized for the layer by the quantity $\Delta_{kp min}$, corresponds to the relative density which is close to the limiting value (≥ 0.9). According to (4) and (5), the method d (Figure 1) is valid only when the striker diameter coincides with D_{min} , and in all other cases either there is no sensitivity phenomenon ($D < D_{min}$ -- secondary explosives), or the influence is greater than the minimum value ($F > F_{min}$ -- highly sensitive initiating explosives). The study [9] proposed a method which approximately satisfies the principle of "minimum influence" (if detonation is used as the positive result of the test). The basic feature of this method, making it possible to find D_{min} experimentally, is the variability of the test conditions: the striker diameter and the explosive density are varied.

We must again turn to the problem of the minimal influence and its characteristics in relationship with the dependence of P_{kp} on the loading system [10,11]. For an experimental study of this problem, a similar dependence was determined of the critical

loading of the TP initiation on the striker* length (Figure 2,a) in a test using scheme b (Figure 1). This scheme for destruction in the case of $P = P_{np}$ is equivalent to scheme a, but is more suitable for an exact measurement of P_{np} using the upper limit of the explosion success [11] (25 tests the test of the pressure change corresponds to the height of the points). The measurement of the loading in a rod with a high frequency sensor showed that a great portion of this dependence corresponds to the interaction of the wave process of the plunger discharge with the charge destruction process, and the upper plateau corresponds to the change to destruction with quasistatic relaxation of the loading system. The dashed line in Figure 2,b shows the change in the initial width of the charge h_0 under critical conditions. The solid line and the dots give the total elastic compression of the loading system

$$\delta = D \left(\frac{1-\nu^2}{\pi} \frac{P}{E} \right)^{2/3} + 2L \frac{P}{E}, \quad (6)$$

which consists of the deformation of two elastic half spaces--the first component [17]; and two rods according to the Hooke law--the second component (E--Young modulus, ν --the Poisson coefficient). The condition $h_0 > h_{nn} > h_0 - \delta$, holds in the relaxation mode, which shows (Figure 2,b) that the greatest value of h_{nn}

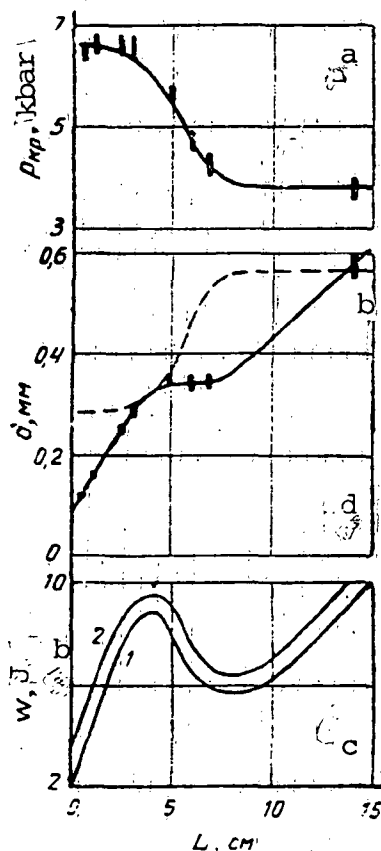


Figure 2. Experimental dependence of the critical loading of tetranitrate pentaerythrite (TP) initiation on the plunger length.

* data were obtained from V. G. Shchetin.

must correspond to a zero plunger length. Figure 1,e shows the scheme for an impact which is close to this case and which in practice is most widely encountered.

The value of the elastic energy in the loading system W^M also is comprised of the plunger energy and the limiting half spaces. This value calculated for the critical conditions, is shown in Figure 2,c (curve 1) as a function of the plunger length. In spite of the non-monotonic nature, it can be clearly seen that the absolute smallest value of energy pertains to the quasistatic case of destruction for $L \rightarrow 0$ and is determined exclusively by the half spaces. Among the numerous real mechanical influences, this case corresponds to the scheme of impact by a limited body using a thin layer of explosive, at rest on an elastic base. The diameter of the loading spot is thus less than the characteristic dimensions of the body (Figure 1,d). Assuming identical properties for the impacting body and the base, for the minimum energy outflow in the "loading system", we obtain

$$W_{min}^M = 1,47 \left(\frac{1-\nu^2}{E} \right)^{2,3} P_{kp}^{6,3} D_{min}^3, \quad (7)$$

which, in combination with the elastic charge compression energy, obtained by integration over the pressure distribution in a thin layer [14] (ν --the volumetric compression modulus)

$$W_{min}^{BB} = 0,12 \frac{\sigma_{np}}{k} (P_{kp} - 0,55\sigma_{np}) D_{min}^3, \quad (8)$$

determines the minimum energy of a dangerous impact with allowance /38 for the collision rigidity. According to (7), the most dangerous solid bodies and bases, which may be classified as real ones, are steel, concrete, etc. Considering the steel bodies as the most rigid ($E = 2.0 \cdot 10^3$ kbar; $\nu = 0.3$), we finally arrive at the energy index of sensitivity $W_{min}^{CT+BB} = W_{min}^{CT} + W_{min}^{BB}$.

The quantity W_{min}^{CT+BB} is determined by the mechanical properties of the explosives (σ_{np} and k), which depend on the initial temperature T_0 and two critical parameters $\Delta_{kp,min}$ ($T_0\mu$) and P_{kp} , which, having only a qualitative explanation, must be measured (μ --kernel diameter). The results of the calculation using data in the

Substance	$\sigma_{np} \cdot 10^3$, kg/cm ²	P_{kp} , kbar	$\Delta_{kp \min}$, mm	D_{\min} , cm	W_{\min}^{CT} , J	W_{\min}^{CT+BB} , J
trotyl	0,47	10,6	$\approx 1,5$	≈ 20	$\approx 10^4$	$\approx 10^4$
tetryl	0,67	8,0	0,55	3,1	80	100
hexogene	1,08	8,0	0,45*	1,5	9,2	12
TP	0,88	6,6	0,22*	0,7	0,8	1,1
lead azide	1,55	$\approx 3,1$	$\approx 0,02$	$\approx 10^{-2}$	$\approx 10^{-6}$	$\approx 10^{-6}$

NOTE: Measured together with И. Бедовым и О. И. Сергиенко.

literature [6,11,15-17] are given in the table. The upper limit of the explosion success using the drop test K-44-III (Figure 1,b; $D = 10$ mm), which satisfies the critical conditions (1)-(2), is used as the quantity P_{kp} at $L \rightarrow 0$. This is done since, due to the presence of a plateau on the dependence of $[P_{kp}(L)]$ their values coincide (Figure 2,a). A smaller amount of impact energy and $W_{\min}^{CT} \approx W_{\min}^{CT+BB}$ is expended on the explosive compression, which may be seen in Figure 2,c, where the quantity W_{\min}^{CT+BB} corresponds to curve 2. It follows from (7) and (5) that W_{\min}^{CT} is determined to the greatest extent by the parameter P_{kp} which, generally speaking, must be measured in the case $D \approx D_{\min}$. TP and hexogene correspond to this condition in the table. With respect to trotyl, for it the value of P_{kp} and W_{\min}^{CT} can be greatly exaggerated since, with an increase in D we must expect an increase in the destruction time and the combustion induction period. Similarly, for lead azide, these quantities are too low. Thus, in connection with the model proposed for the minimum influence, in the problem of determining the sensitivity of solid explosives to impact, we propose the study of the dependence $P_{kp}(D)$ and the development of similar methods for measuring D_{\min} and W_{\min}^{CT+BB} , and just as earlier, a determination of the conditions when the impact danger is limited by the second stage.

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